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(21) International Application Number: PCT/GB95/03030 (22) International Filing Date: 22 December 1995 (22.12.95) (30) Priority Data: 9523580.0 17 November 1995 (17.11.95) GB (71) Applicant (for all designated States except US): AROMAS-CAN PLC [GB/GB]; Electra House, Electra Way, Crewe, Cheshire CW1 1WZ (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): DOWDESWELL, Richard, Mark [GB/GB]; 36 Park Hill Avenue, Manchester M8 4RA (GB). AMRANI, Mohammed, El Hassan [DZ/GB]; 33 Skerry Close, Brunswick, Manchester M13 9UD (GB). PAYNE, Peter, Alfred [GB/GB]; 13 Chelworth Manor, Manor Road, Bramhall, Cheshire SK7 3LX (GB). PERSAUD, Krishna, Chandra [GY/GB]; 65 Mersey Bank Avenue, Chorlton, Manchester M21 7NT (GB). (74) Agents: McNEIGHT, David, Leslie et al.; McNeight & Lawrence, Regent House, Heaton Lane, Stockport, Cheshire SK4 1BS (GB).		(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>
(54) Title: GAS ANALYSIS (57) Abstract There is disclosed a method of analysing a gas sample comprising the steps of: exposing at least one gas sensor to said sample; applying an alternating electric signal to the sensor or sensors; varying the frequency of the alternating signal; detecting or calculating an impedance characteristic of the sensor or sensors as a function of frequency; and comparing the impedance characteristic, or characteristics, to impedance characteristics obtained in like manner by exposing the sensor or sensors to gases or gas mixtures of known composition.		

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GAS ANALYSIS

This invention concerns a method for analysing the composition, concentration and relative abundances of gases and mixtures of gases, with particular reference to the use of alternating electric signals to interrogate a gas sensor.

The use of semiconducting organic polymers (SOPs) as the active sensing medium in a variety of gas sensors is well established. Typically, a sensor comprises a pair of electrodes bridged by at least one layer of SOP; transduction is usually accomplished by measuring changes in the dc resistance of the sensors, these changes being induced by adsorption of gaseous species onto the polymer (see, for example, Persaud KC, Bartlett JG and Pelosi P, in "Robots and Biological Systems: Towards a new bionics?", Eds. Darios P, Sandini G and Aebischer P, NATO ASI Series F: Computer and Systems Sciences 102 (1993) 579). When used in conjunction with dc transduction, SOP's are not selective: a given SOP is sensitive to a range of species, perhaps a series of homologues possessing a functional group to which the polymer is responsive. In order to achieve chemical selectivity, arrays of sensors (often 20 or more) are employed, wherein each sensor utilises a different SOP and the SOPs employed possess differing but broadly overlapping sensitivities towards a range of molecules. Selective recognition of a given species is thus possible, since the pattern of sensor response across the array represents a characteristic molecular "fingerprint".

However, identification of the components of mixtures - even binary mixtures - of gases is a far harder task, and the prediction of the relative proportions of gases in such mixtures is harder still, certainly to within acceptable ($\pm 5\%$) error limits.

The dc transduction/sensor array approach is completely unable to determine relative proportions of components in a tertiary or greater mixture.

British Patent GB 2 203 553 discloses an improved method of sensor transduction wherein an ac electric signal is applied to a single sensor, and variations in an impedance characteristic are detected as a function of the applied ac frequency. In this instance, the spectrum of impedance characteristic variation against ac frequency provides the species specific “fingerprint”, with the promise that a single sensor may be employed in the place of a sensor array. However, the detection of mixtures of gases is not disclosed in GB 2 203 553.

In the present invention, refinements have been made to the ac transduction technique which enable the composition of a gas or a mixture of gases to be determined. In one aspect of the invention, the previously intractable problem of determining the relative proportions of gases in a tertiary or quaternary mixture thereof using SOP based gas sensors is overcome. It is noted that the term “gas” encompasses any gas phase species, such as vapours.

According to a first aspect of the invention, there is provided a method of analysing a gas sample comprising the steps of:

- exposing at least one gas sensor to said sample;
- applying an alternating electric signal to the sensor or sensors;
- varying the frequency of the alternating signal;
- detecting or calculating an impedance characteristic of the sensor or sensors as a function of frequency; and

comparing the impedance characteristic, or characteristics, to impedance characteristics obtained in like manner by exposing the sensor or sensors to gases or gas mixtures of known composition.

A primary motivation is to determine the composition of a mixture of gases, although the method may also be used to determine the identity of a pure but unknown gas sample, or to determine if the gas sample is pure, or to differentiate between samples of different, but unknown, composition.

The comparison may be made by employing a neural network.

The sensor or sensors may comprise at least one semiconducting organic polymer.

The resistance, reactance or dissipation factor of the sensor or sensors may be measured or calculated as a function of frequency, since these impedance characteristics are particularly sensitive indications of mixture composition.

The mixture may be a tertiary mixture or greater.

The method may be used to determine the relative proportions of each gas in a mixture of known chemical composition.

According to a second aspect of the invention there is provided apparatus for gas sample analysis comprising :

at least one gas sensor;

means for applying an alternating electric signal to the gas sensor or sensors in the presence of said gas sample;

means for detecting or calculating an impedance characteristic of the sensor or sensors as a function of frequency; and

comparison means for comparing the impedance characteristic, or characteristics, to impedance characteristics obtained in like manner by exposing the sensor or sensors to gases or gas mixtures of known composition.

The comparison means may comprise a neural network.

The sensor or sensors may comprise at least one semiconducting organic polymer.

A method of determining the composition of a gas sample in accordance with the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram of apparatus according to the invention;

Figure 2 shows dissipation factor vs frequency for five beer vapours;

Figure 3 shows resistance and reactance vs frequency for five beer vapours;

Figure 4 shows dissipation factor vs frequency for acetone, methanol, and combinations thereof;

Figures 5-8 show network responses to various methanol/acetone mixtures;

Figure 9 shows dissipation factor vs frequency for acetone, methanol, ethyl acetate and combinations thereof;

Figures 10-14 shows the network response to acetone, methanol, ethyl acetate and combinations thereof;

Figure 15 shows the network response to an unknown combination of acetone, methanol and ethyl acetate;

Figure 16 is a plot of dissipation factors against frequency for various quaternary mixtures; and

Figures 17-21 show the network response to acetone, ethyl acetate, methanol, acetonitrile and mixtures thereof.

Figure 1 shows a schematic diagram of an apparatus for analysing volatile liquids by detection of the vapours associated therewith. The vapour from a volatile liquid or mixture of liquids 10 contained in a glass container is entrained in a stream of dry air 12, and the gas sensor 14 is exposed thereto. Measurements are made

using an impedance analyser 16 (Hewlett-Packard model 4192A). The impedance analyser 16 and data acquisition system are controlled by computer 18.

Experiments have been performed on vapours emanating from five samples of different commercially available beers. Vapour was entrained in dry air at a flow rate of 0.25 lmin^{-1} and passed over the gas sensor 14, which was fabricated from N-decyl pyrrole (although it is understood that this in no way limits the scope of the invention thereto). The impedance quantity detected - or, strictly speaking, calculated - for the present purposes is the dissipation factor DF, which is related to the real (resistive) and imaginary (reactive) parts of the measured impedance by the following:-

$$DF = \frac{R}{|X|} \quad (1)$$

where R is the resistance and X the reactance. R and X were measured in the frequency range 800-1000 KHz in steps of 0.2KHz, measurements being repeated six times for each sample of beer.

Figure 2(a) shows the response of the gas sensor to the five types of beer in the applied frequency range 800-1000 KHz. Two clusters of dissipation factor peaks occur in the ranges 840-880 KHz and 930-960 KHz, as shown in Figures 2(b) and 2(c) respectively. The fact that two peaks are observed in each measurement reflects the fact that the reactance goes from negative to positive to negative (with increasing frequency) in this frequency range (see Figure 3(b)). The second set of peaks (from 880-930KHz) is mainly due to a combination of capacitive and conductive effects. In this frequency region, the sensor displays a distinct dissipation peak for each type of beer, indicating

that identification of beer type via analysis of its vapour is possible. Such identification could be performed, for example, by direct comparison with standard dissipation factor patterns, or by the use of a neutral network. It should be noted that measurements are extremely reproducible.

The dissipation factor would appear to be the detected impedance characteristic of choice, since - i) the frequency and amplitude of both peaks vary from beer to beer, and - ii) the peaks are characteristic, distinctive, resonant features which occur on a near zero background. The latter feature is in direct contrast to the dc transduction technique, wherein relatively small changes in dc resistance occur on a large background. This feature is also in direct contrast to British Patent GB 2 203 533, wherein ac techniques were employed to measure variations in impedance characteristics caused by exposure of a gas sensor to a gas, these variations being measured with respect to some reference spectrum. Thus the method of GB 2 203 533 suffers from an identical disadvantage to dc transduction technique, that measurements rely on the detection of relatively small changes in a large and probably fluctuating background signal. In the present invention the absolute impedance characteristics of the sensor in the presence of the gas sample are measured. In addition to the selectivity afforded by the technique, the magnitude of the dissipation factors presented in Figure 2 suggests that excellent sensitivity is possible. Furthermore, it appears that either the area of a dissipation factor peak, or the height thereof, is proportional to vapour concentration, suggesting that quantitative measurements may be made. However, see below for some cautionary remarks upon the interpretation of the amplitude of the dissipation factor peak.

Figures 3(a) and 3(b) show the resistive and reactive parts of the impedance respectively, in the presence of the five types of beer in the frequency range 800-1000KHz. Although these data are less distinctive than the dissipation factor, it is perfectly feasible that either of these impedance characteristics may be used for the purposes of the present invention, i.e. that the impedance characteristic itself, rather than a difference spectrum, is used for identification of a gas sample. It may be possible to use the resonant frequencies - in other words, the frequencies at which the reactance becomes zero - to identify a gas or gas mixture. The resonant frequencies are, of course, the frequencies at which peaks are observed in the dissipation factor spectrum. Other impedance quantities may prove amenable to use in the present invention.

Experiments have also been performed on binary mixtures of methanol and acetone, tertiary mixtures of methanol, acetone and ethyl acetate, and quaternary mixtures of methanol, acetone, ethyl acetate and acetonitrile. The relative proportions of the liquids in the mixture 10 can be determined by using a defined number of moles of each liquid. The corresponding liquid volume V required can be easily calculated from the following relationship

$$V = \frac{MW \times M}{D} \quad (2)$$

where MW is the molecular weight, M is the number of moles required and D is the density of the liquid.

It should be noted that the relative proportions of components derived in this manner apply to the composition of the liquid. The ratio of the gas phase vapour

components will, of course, depend on the liquid phase ratio, the partial pressures of the liquid components and any deviation away from ideal solution behaviour.

For the measurement of binary and tertiary mixtures the N-decyl pyrrole gas sensor 14 was exposed to a vapour mixture containing air stream 12 for three minutes - allowing sensor response to stabilise before measurements were made.

Dissipation factor was calculated from values of R and X measured between 800 and 1100 KHz in steps of 1.2 KHz although for the purpose of Figure 4, which shows the dissipation factor of the sensor in the presence of pure acetone, pure methanol, and various mixtures thereof, data are presented in the range 800 to 930 KHz.

Once again, two distinctive dissipation factor peaks are observed in each measurement, and similar comments to those made in relation to Figure 2 pertain. However, it should be noted that, whilst each mixture represented in Figure 4 gives rise to a distinctive response, the overall pattern is rather complicated and difficult to analyse.

The analysis of dissipation factor data was performed on the computer 18 using a neural network software package (NeuralDesk) employing both Standard Back propagation and Stochastic Backpropagation algorithms. For the binary mixture of acetone and methanol, a training data file was constructed which included equal numbers of the five compositions displayed in Figure 4. Data below 967 KHz only were used for training of the network since no peaks were detected at higher frequencies, and this more limited frequency range permitted the use of only 139 inputs, reducing the task of network training. The data were normalised to the range zero to one prior to network training. The network consisted of 139 inputs, 40 hidden nodes and two output nodes.

Training was terminated when the maximum error of the training set reached values between 0.1 and 0.05, typically requiring between 132 and 1519 interactions (depending upon the convergence criteria and the algorithm used). The networks were then tested with previously unseen sets of patterns derived from exposure of the sensor to acetone and methanol present in different ratios to the training ratios. The responses of the networks are recorded in Figures 5 to 8.

Composition analysis of tertiary vapour mixtures was performed using mixtures of ethyl acetate, methanol and acetone in various fractional abundances. A network training pattern was constructed which consisted of 139 inputs (representing the frequency range 800 to 967 KHz), 40 hidden nodes and three output nodes each of which represented the fractional abundance of a different component. The highly complex nature of the training data is revealed in Figure 9, which shows dissipation factor against frequency for various tertiary vapour mixtures. Rather large dissipation factors are recorded for some mixtures, and thus for the purposes of analysis a ceiling of 400 was imposed upon the data. In other words, any values above 400 were assigned the value 400, an operation which retained some data patterns which would otherwise have been lost on scaling. Training of the network was conducted with the NeuralDesk software package and utilised the Stochastic Backpropagation routine. Training of the network required 405 iterations to reach a convergence criterion of 0.1 maximum error in the training data set. Upon convergence the network was presented with a series of test patterns; the resulting network classifications of mixture composition are shown in Figures 10 to 14.

Figure 15 shows the response of the trained network to a previously unseen mixture composed of 20% ethyl acetate, 50% methanol and 30% acetone. The prediction of the network is within the 5% network training error, a level of accuracy which could be improved upon further by utilising more training data relating to further compositions.

It is pertinent to consider the reliability and reproducibility of the dissipation factor amplitudes. At first sight, the imposition of a ceiling of 400 on the data patterns would appear to have the effect of rejecting some of the peak amplitude information displayed in Figure 9. However, it has been observed that peak amplitudes can vary from measurement to measurement by up to a factor of 5, and therefore the ceiling value may have the effect of protecting against these variations to some extent. Undoubtedly the variations are mainly due to temperature drifts which have the effect of shifting slightly the resonant frequency. Since the measured reactance is by definition very small near resonance, even small resonant frequency shifts can result in a large relative change in the measured reactance, which propagates through into a large variation in the dissipation factor peak amplitude. No variation is observed in the frequency of the dissipation factor peak, indicating that the temperature dependent resonant frequency variation is small compared with the impedance analyser frequency step size employed (1.2 KHz).

One solution would be to maintain the gas sensor at a fixed temperature. It is also feasible to obtain a peak value by extrapolation of neighbouring dissipation factors values - these values being virtually constant from measurement to measurement. However, it is likely that the peak values are not necessary for analysis by the neural network. After training, significant weighting factors are attached to many of the inputs

across the whole of the frequency range scanned. This indicates that data from across the whole of the frequency range, including 'baseline' dissipation factor values, are important in pattern recognition.

Notwithstanding these comments the experiments described herein - without any form of temperature stabilisation - have successfully analysed the compositions of tertiary mixtures and, as described below, quaternary mixtures. Temperature dependent effects around resonance will become more important as the frequency step size is decreased.

Figures 16 to 21 show the response of the network to samples comprising 100% acetone, 100% ethyl acetate and 100% methanol, and quaternary mixtures of these compounds with acetonitrile in various relative abundancies. Clearly, mixtures with even more components could be analysed.

For the preparation of the responses shown in Figures 16 to 21, twenty eight different quaternary mixtures were prepared using the molar concentration method. The indicated mixture concentrations are, as before, in the liquid phase.

The same gas flow system as used for the binary and tertiary mixtures was utilised for the quaternary mixtures.

The real (R) and imaginary (X) parts of the impedance of the gas sensor are measured between 850 KHz and 950 KHz by steps of 0.4 KHz (convenient for the Network format i.e. requiring up to 250 readings for each set of measurement) using the

Hewlett-Packard model 4192A impedance analyser. The dissipation factor was automatically computed from the real and imaginary part of the impedance measured, using as before, the relationship:

$$DF = \frac{R}{|X|}$$

For the quaternary mixture of methanol, acetone, ethyl acetate and acetonitrile a training data file was constructed which included equal numbers of 28 compositions used in the experiment. Examples of each training pattern are illustrated in Figure 16 which shows a plot of dissipation factor against frequency for the various mixture compositions. A network training pattern was constructed consisting of 250 inputs (representing the frequency range 850 KHz to 950 KHz by steps of 0.4 KHz) 40 hidden nodes and four outputs which represented the fraction of each component. The complex nature of the training data is illustrated in Figure 16. Due to the high dissipation factor values reported for some of the mixtures a ceiling of 700 was placed on the data any values above this were simply reported as 700. This had the effect of retaining more of the data's pattern which would have otherwise been lost once the data had been scaled. Training of the network was again conducted using the NeuralDesk software package and utilised the Stochastic Back Propagation routine. Training of the network took 1214 iterations to reach a convergence criterion of 0.05 maximum error in the training data set. This took approximately 15 hours on a P90 based PC. Once this network had converged it was presented with a series of test patterns and the network predictions of compositions are illustrated in Figures 17-21.

It should be noted that the interpolation between training data sets required to predict the composition of a new mixture is a non-trivial task. Although the mixture compositions in the liquid change in a linear fashion, the associated dissipation factor peak frequency and amplitude variations follow an extremely complicated relationship. This relationship depends upon inter-alia the inherent response and sensitivity of the polymer to the various components of the mixture. Further response non-linearities would be introduced by any deviation of the mixture from ideal solution behaviour and any changes in the competition for polymer binding sites occurring with changing vapour pressure (which itself is a function of mixture composition).

Although neural network algorithms are particularly well suited to such predictive interpolation, other methods, such as fuzzy logic, may be applied for this purpose. An unsophisticated variation would be to compare the detected impedance characteristic of the unknown mixture with a series of standards measured with known compositions. However, the complicated relationship between dissipation factor and mixture composition dictates that a large number of standards would be required by such a "brute-force" approach.

The use of a plurality of sensors, each utilising a different SOP and multiplexed to the impedance analyser, is within the scope of the invention. The extra information derived from such an approach would permit more accurate determination of mixture composition. In another variation still the neural network would be trained with various combinations of gases (e.g. binary and tertiary) at different mixing ratios, the gases being selected from a group of chemicals. In this manner, the system could detect the identities of components in addition to the fractional abundances thereof.

CLAIMS

1. A method of analysing a gas sample comprising the steps of :
exposing at least one gas sensor to said sample;
applying an alternating electric signal to the sensor or sensors;
varying the frequency of the alternating signal;
detecting or calculating an impedance characteristic of the sensor or sensors
as a function of frequency; and
comparing the impedance characteristic, or characteristics, to impedance
characteristics obtained in like manner by exposing the sensor or sensors to gases or gas
mixtures of known composition.
2. A method according to claim 1 in which the comparison is made by
employing a neural network.
3. A method according to claim 1 or claim 2 in which the sensor or sensors
comprise at least one semiconducting organic polymer.
4. A method according to any of the previous claims in which the resistance,
reactance or dissipation factor of the sensor or sensors is measured or calculated.
5. A method according to any of the previous claims in which the identity of
a gas or gases present in the gas sample is determined.

6. A method according to any of the previous claims in which a tertiary or greater gas mixture is analysed.
7. A method according to any of the previous claims in which the relative proportion of each gas in a gas mixture of known chemical composition is determined.
8. Apparatus for gas sample analysis comprising :
 - at least one gas sensor;
 - means for applying an alternating electric signal to the gas sensor or sensors in the presence of said gas sample;
 - means for detecting or calculating an impedance characteristic of the sensor or sensors as a function of frequency; and
 - comparison means for comparing the impedance characteristic, or characteristics, to impedance characteristics obtained in like manner by exposing the sensor or sensors to gases or gas mixtures of known composition.
9. Apparatus according to claim 8 in which the comparison means comprises a neural network.
10. Apparatus according to claim 8 or claim 9 in which the sensor or sensors comprise at least one semiconducting organic polymer.

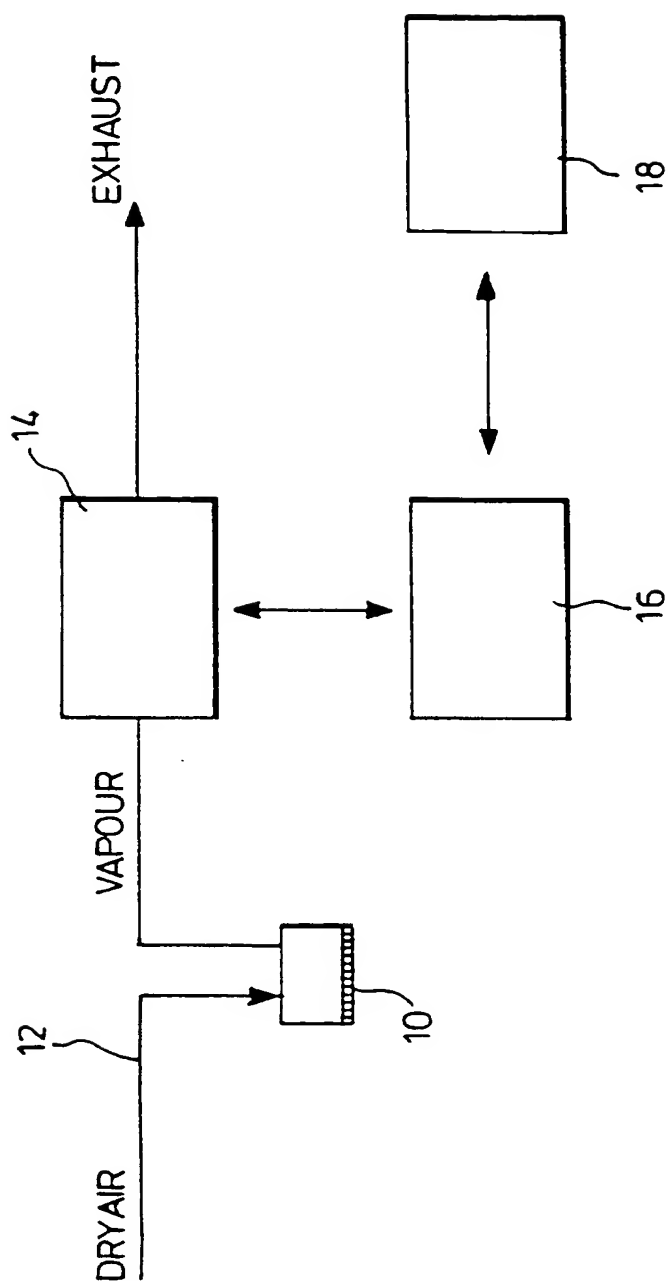
FIG. 1

Figure 2
AC RESPONSE OF N4 GAS SENSOR TO FIVE TYPES OF BEER

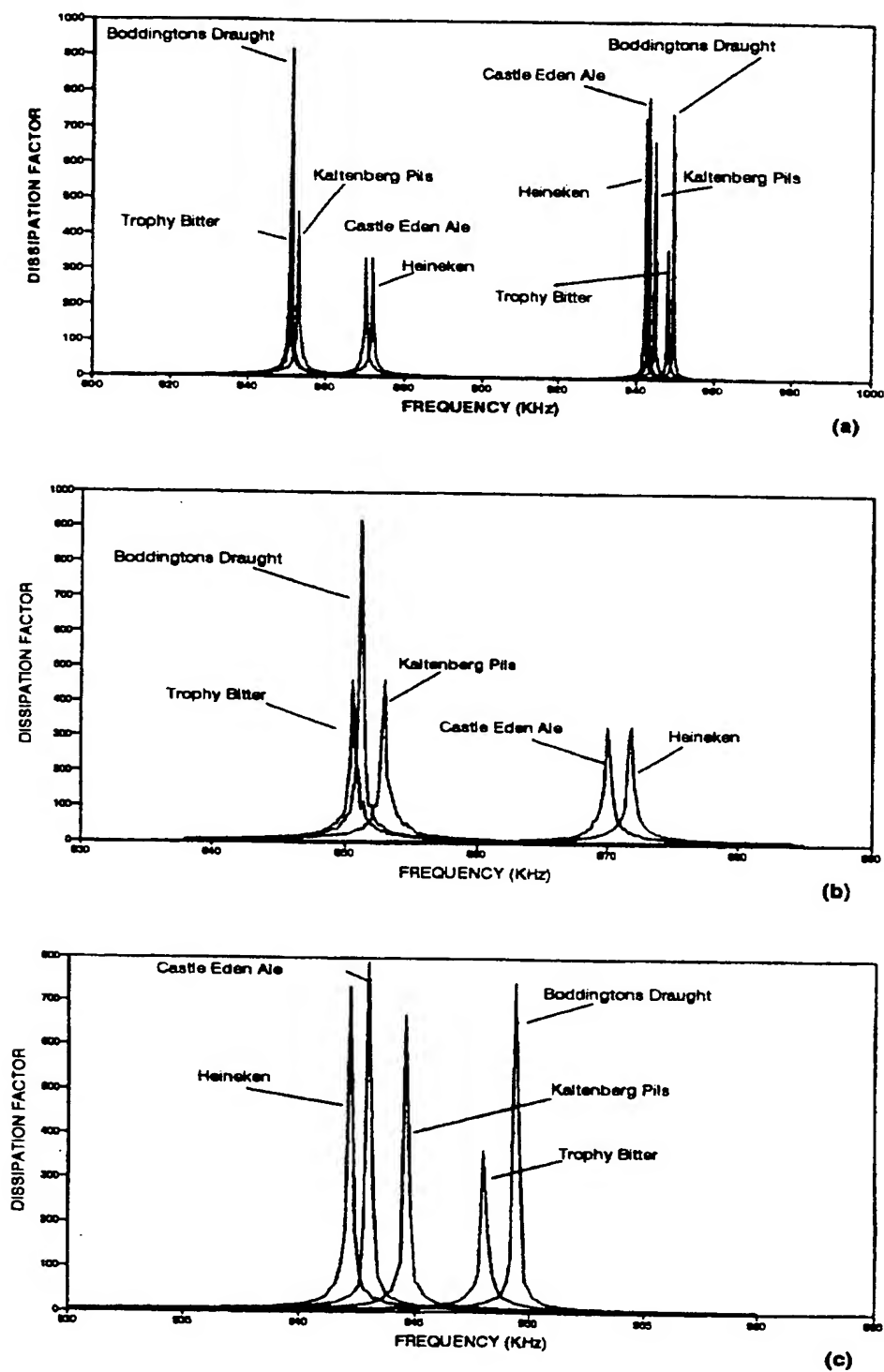


Figure 3
AC RESPONSE OF N4 GAS SENSOR TO FIVE TYPES OF BEER

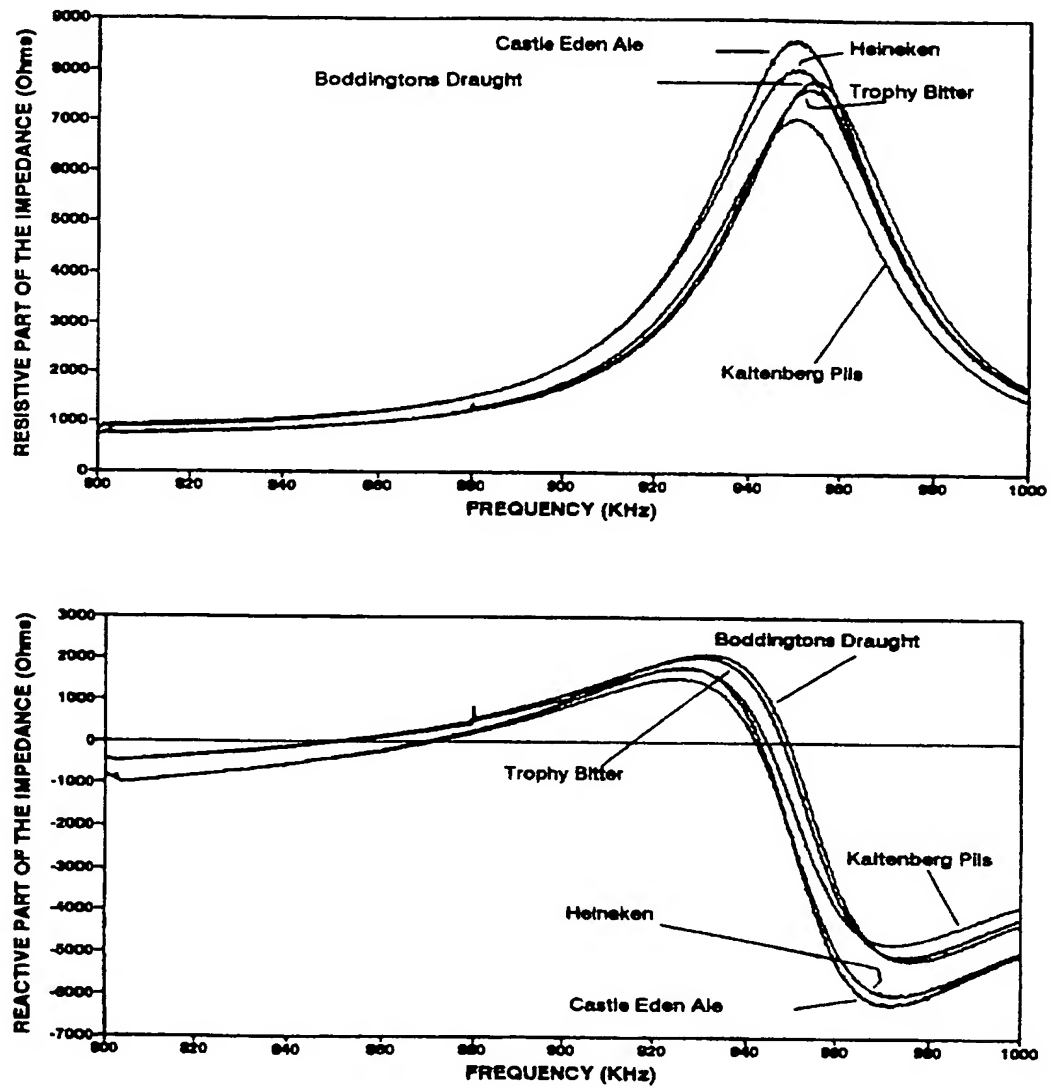


Figure 4
AC response of two component vapour mixtures

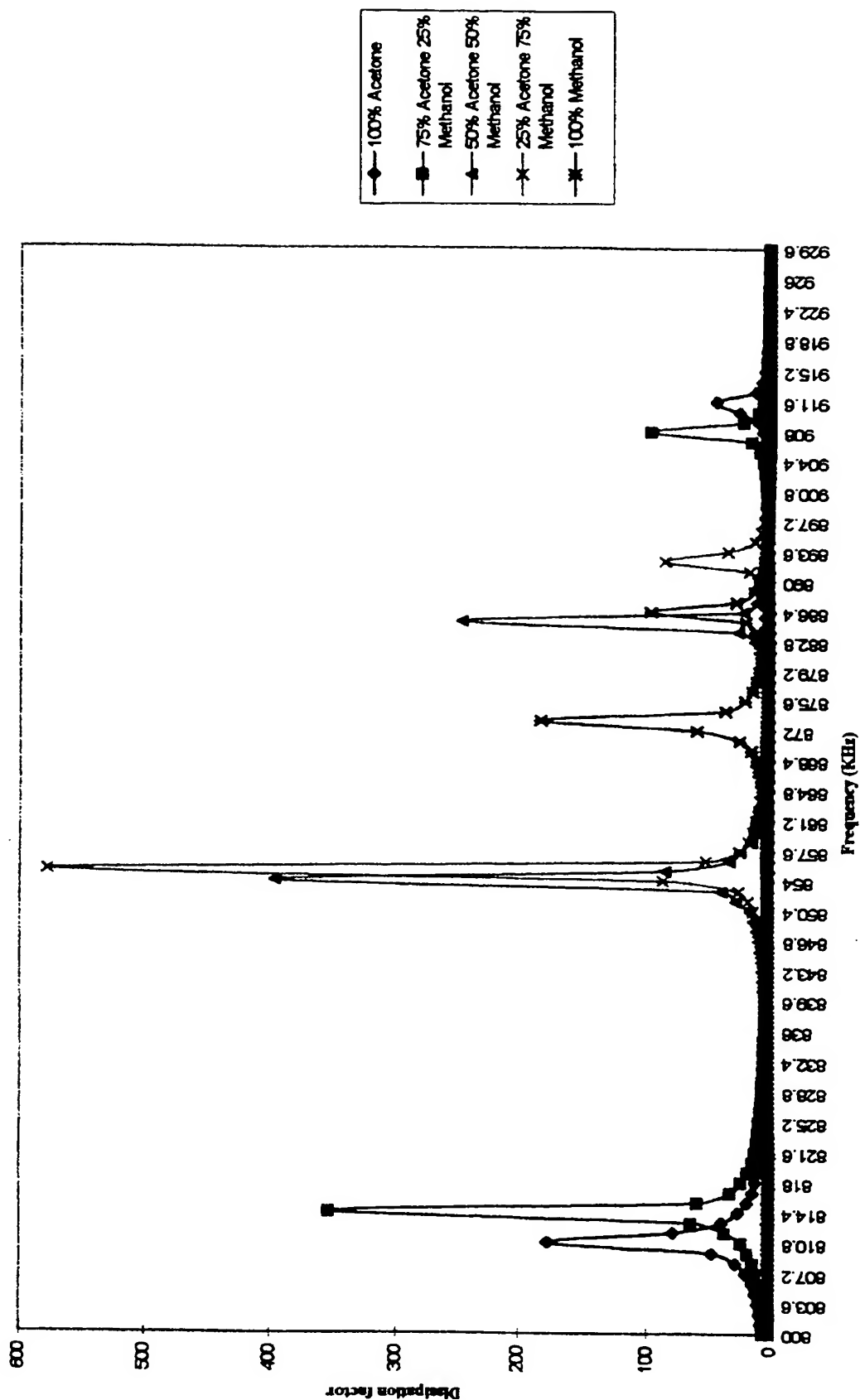


Figure 5
Stochastic BP Network (0.1 max training error)

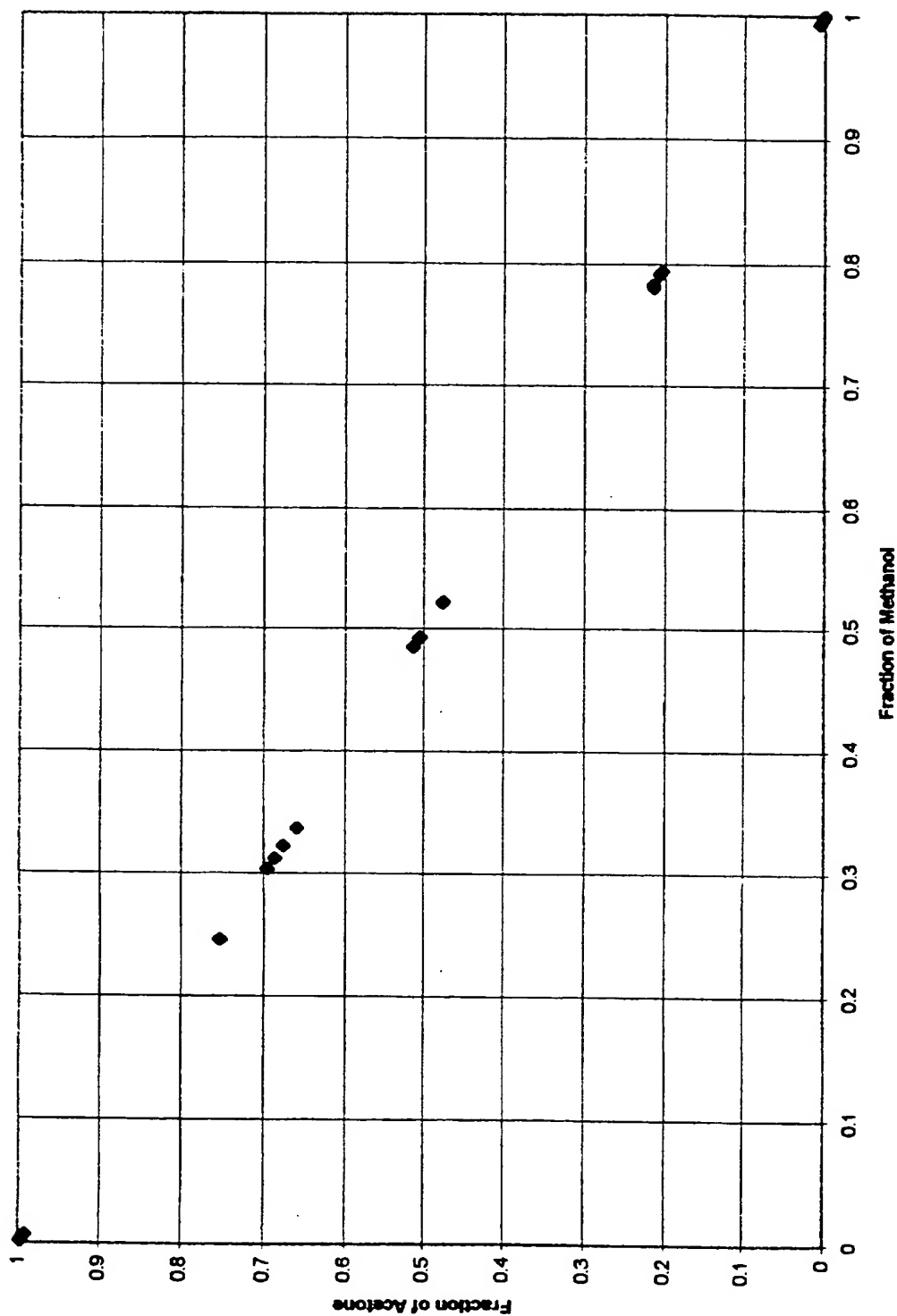


Figure 6
Standard BP Network (0.1 max training error)

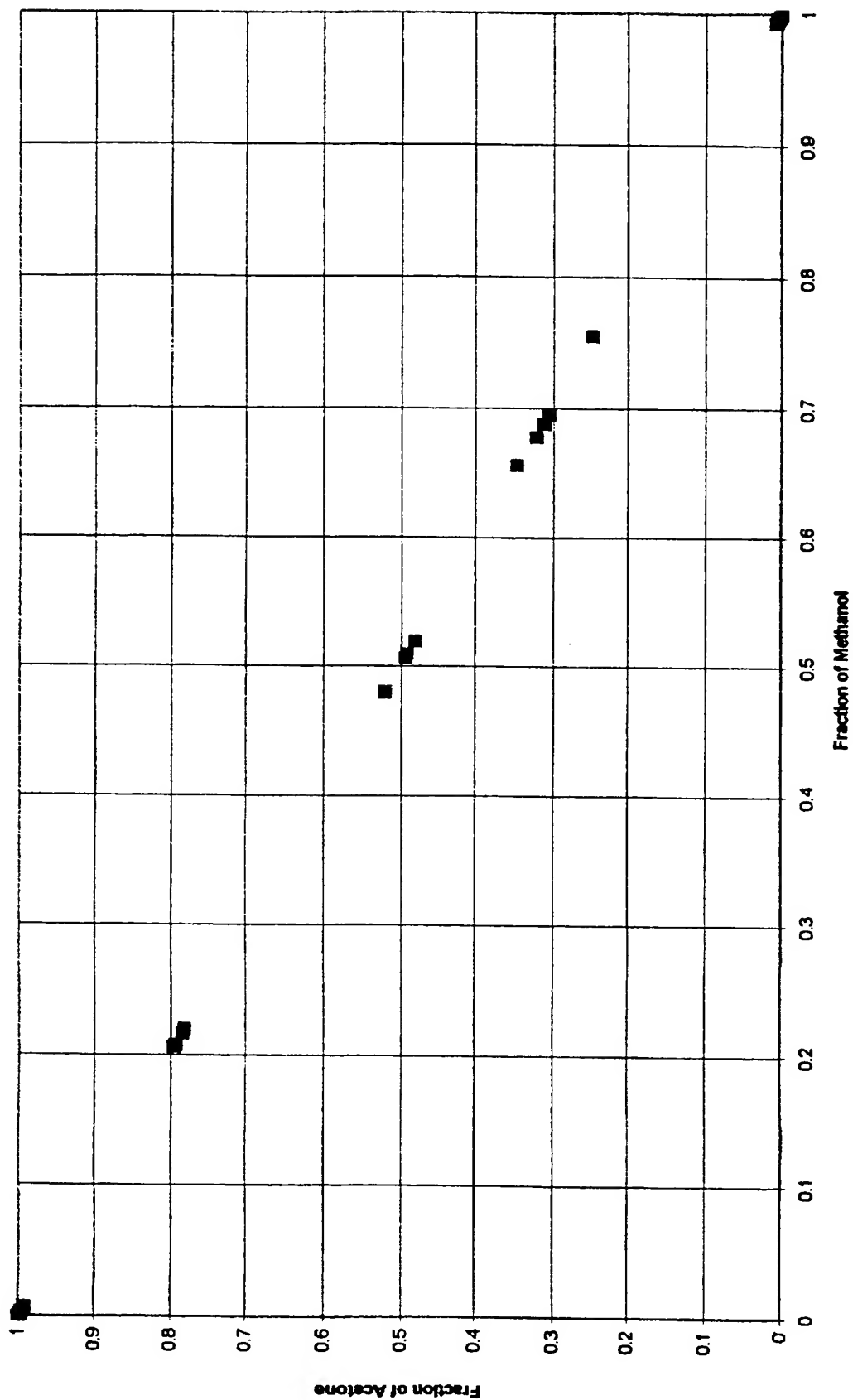


Figure 7
Standard BP Network (0.05 max training error)

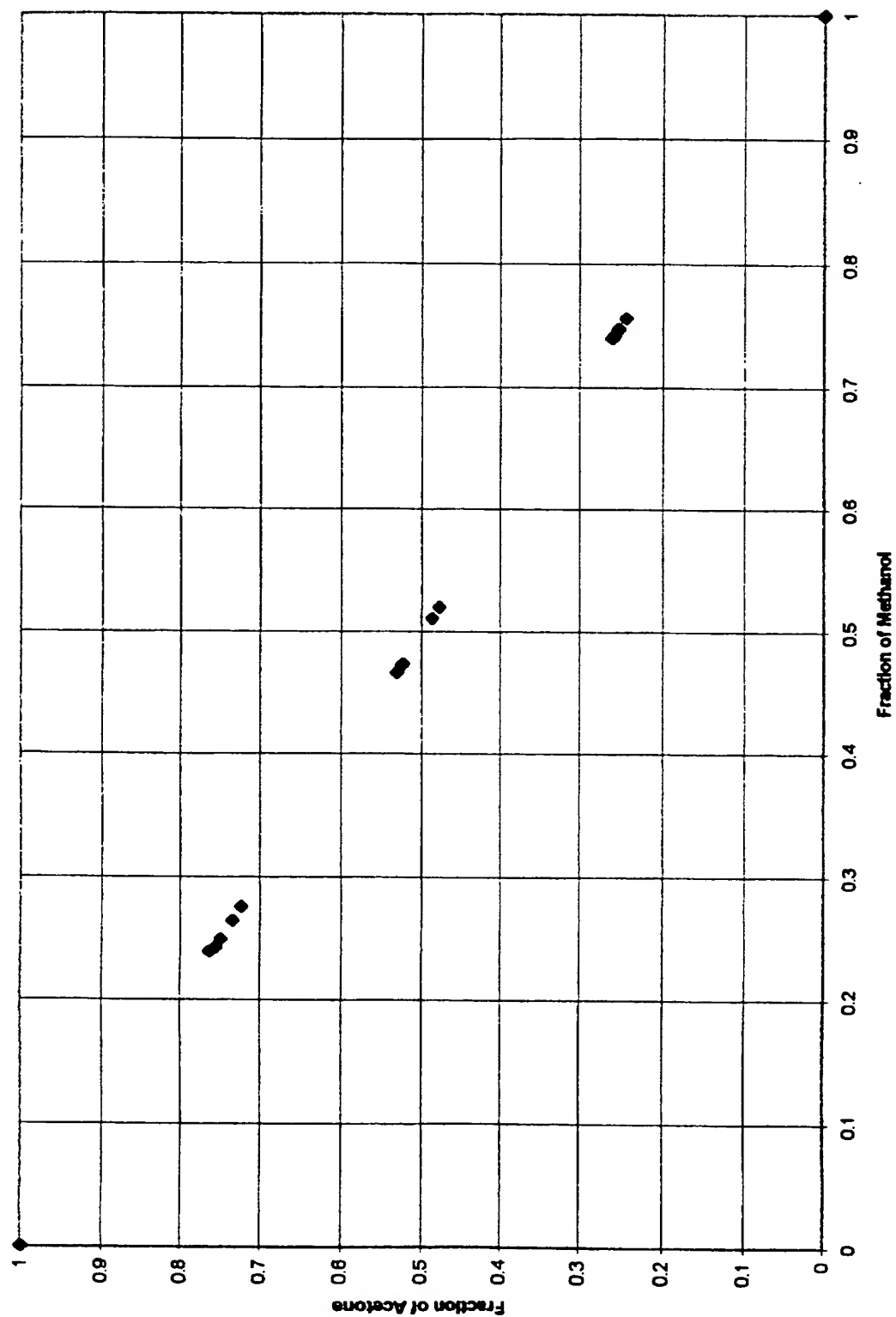


Figure 8
Stochastic BP Network (0.05 max training error)

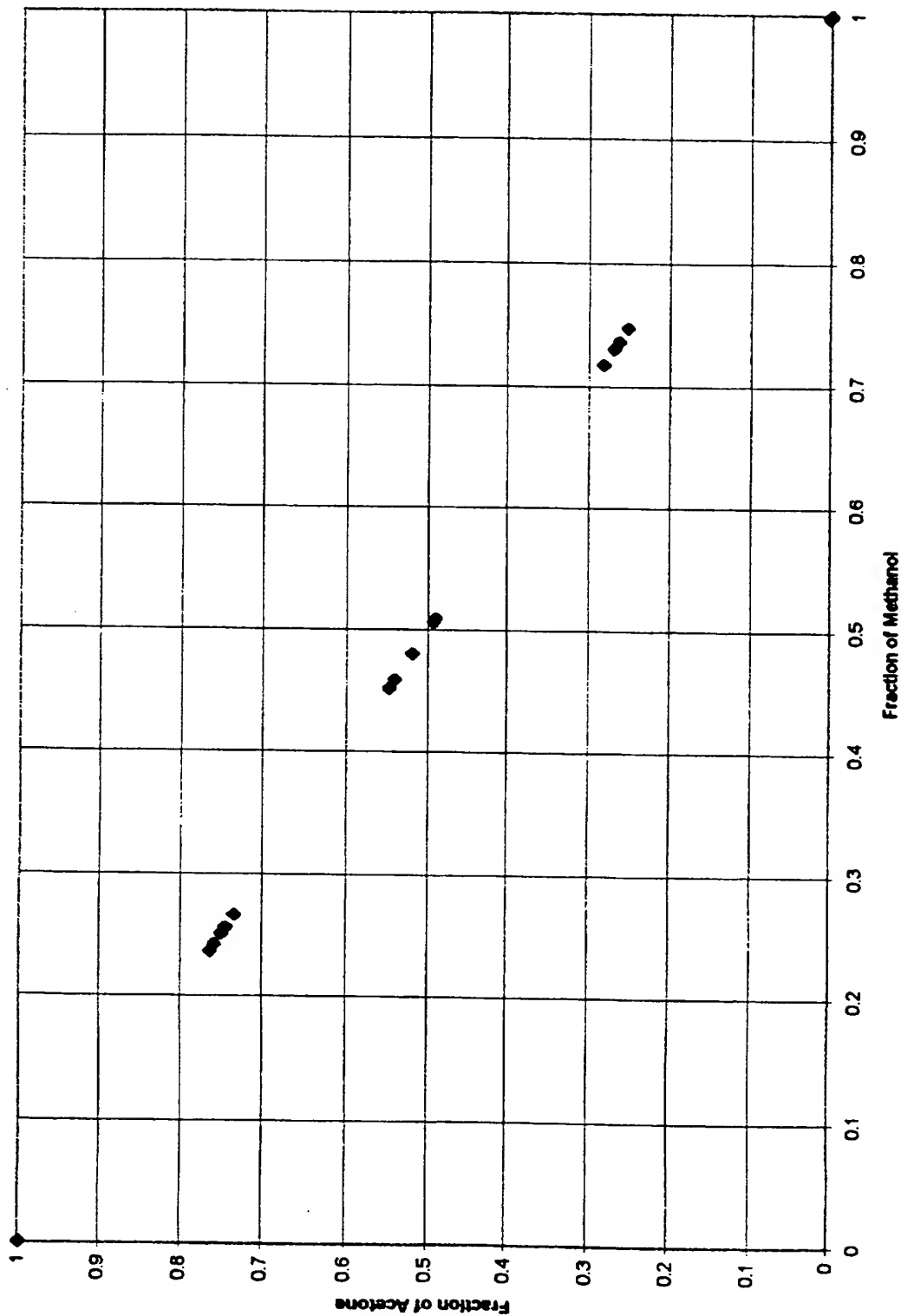
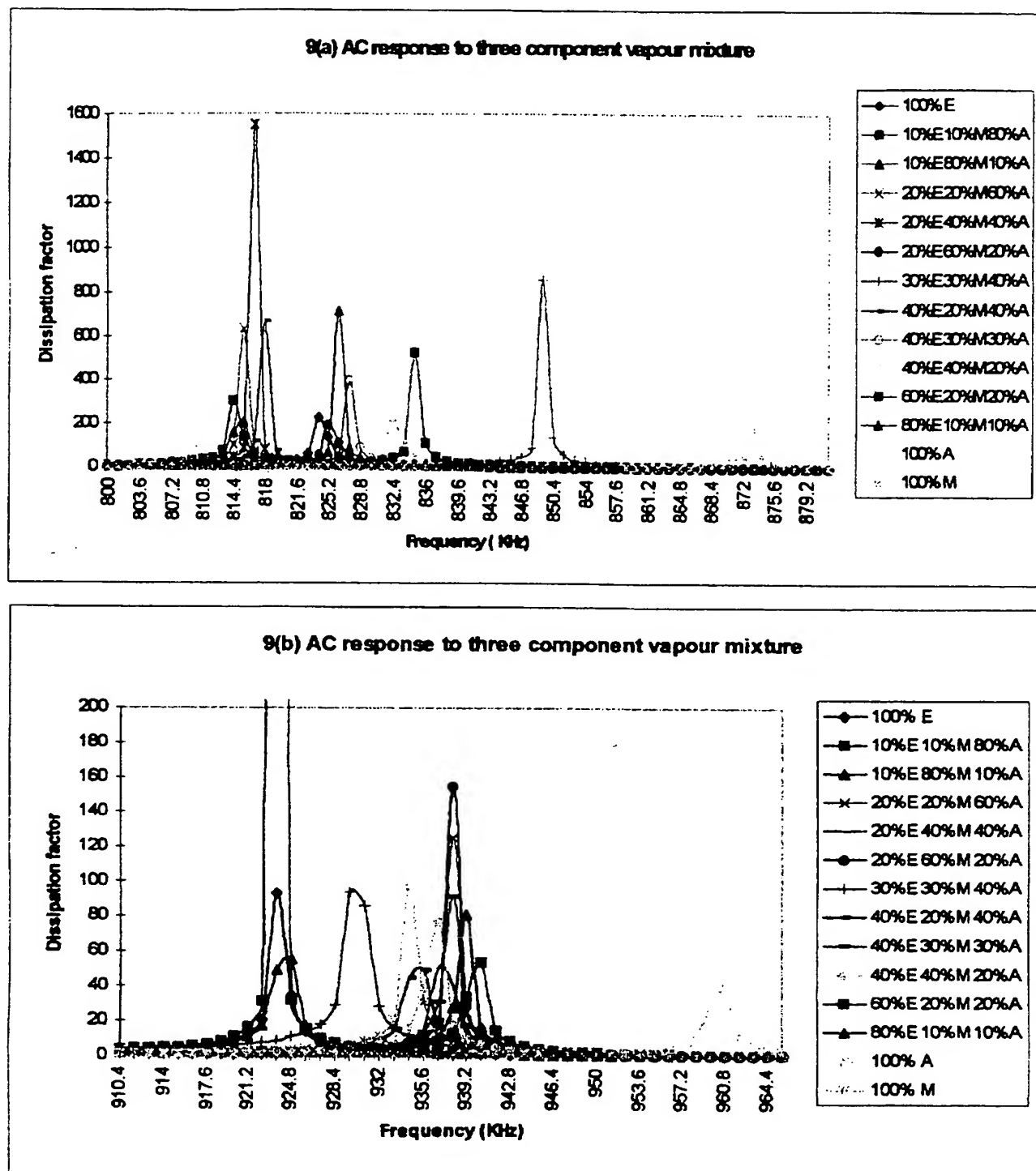


Figure 9



E=Ethyl Acetate, M=Methanol, A=Acetone

Figure 10
Results of neural network classifications for multi-component vapours

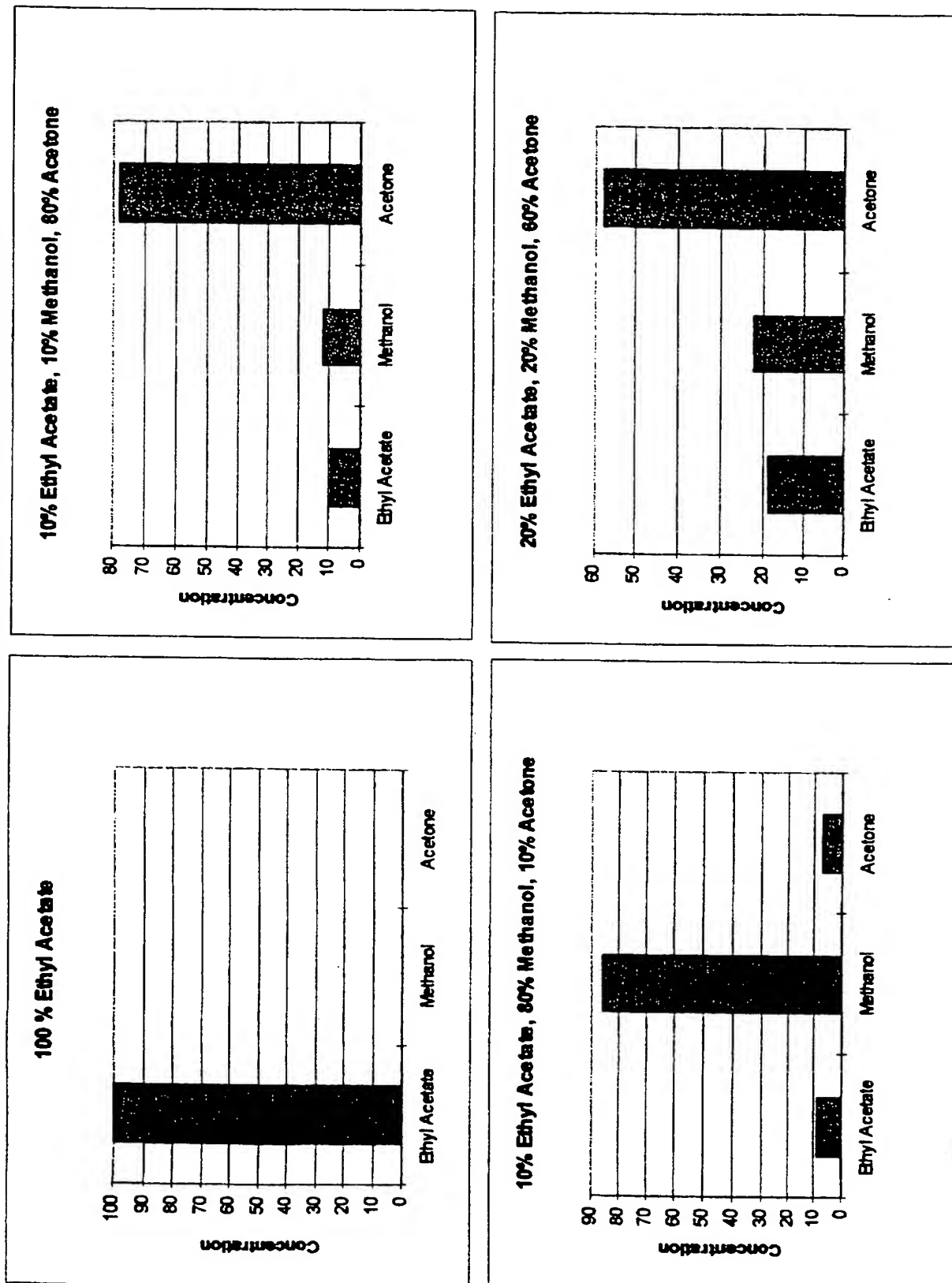


Figure 11
Results of neural network classifications for multi-component vapours

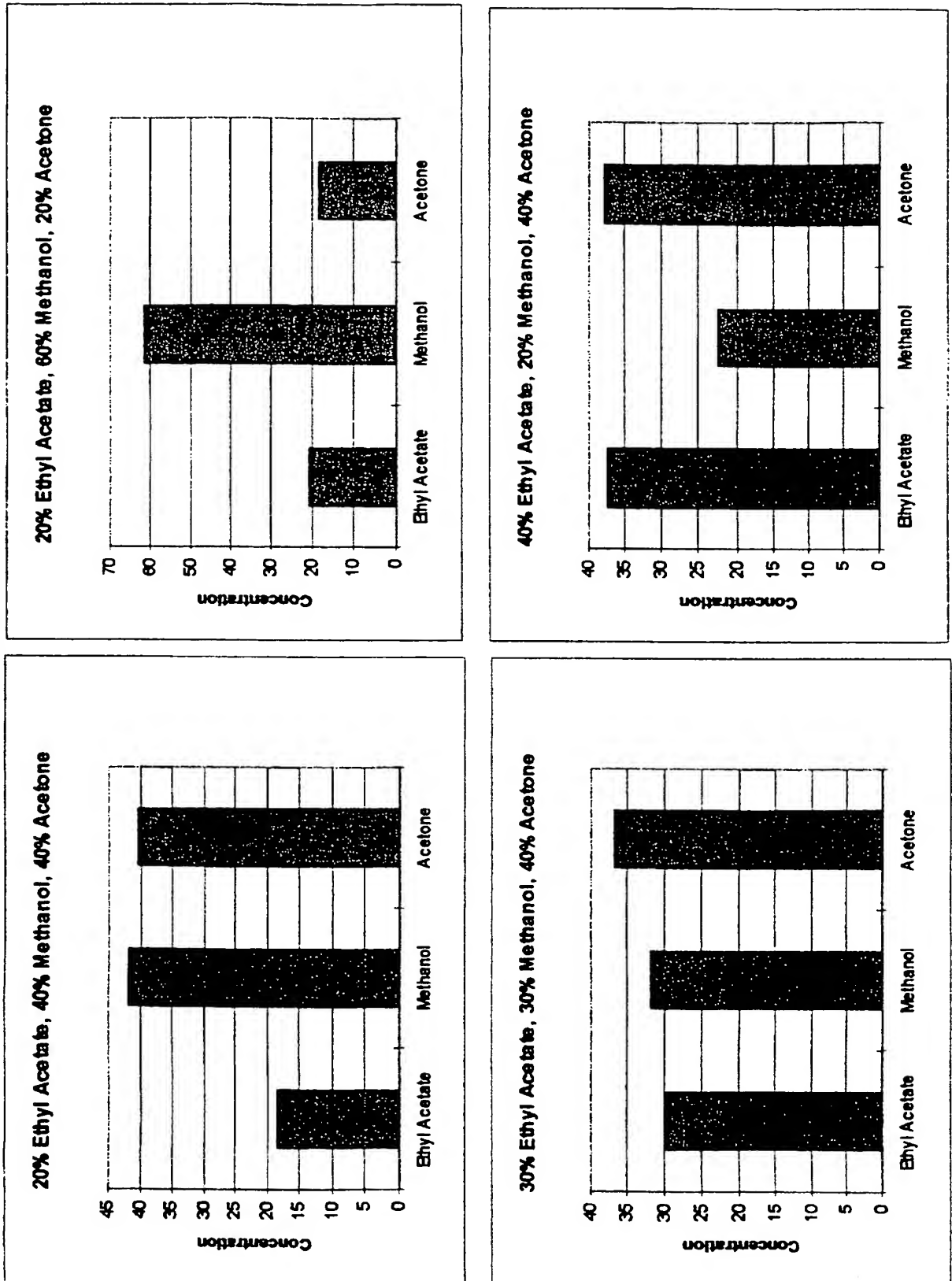


Figure 12
Results of neural network classifications for multi-component vapours

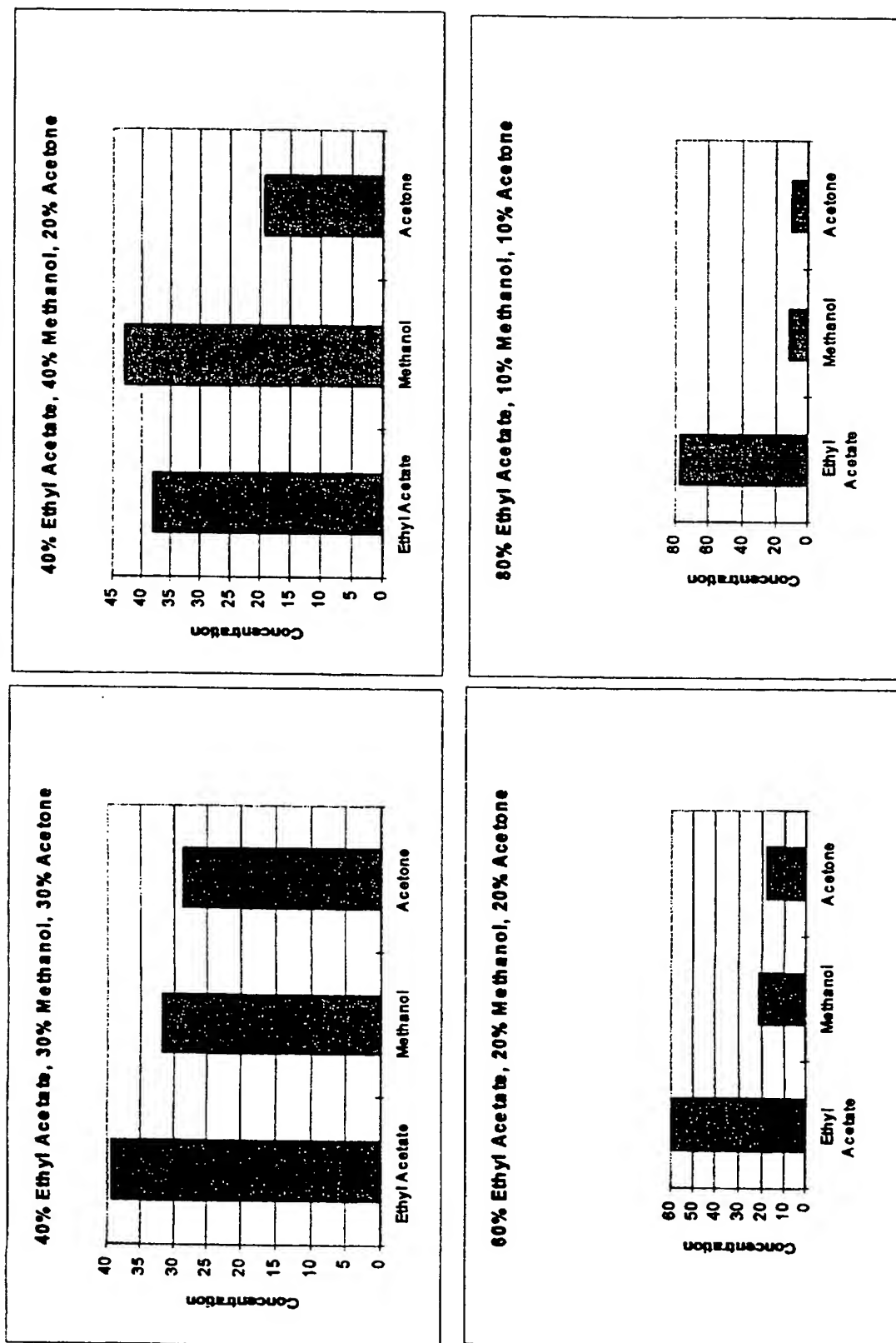


Figure 13
Results of neural network classifications for multi-component vapours

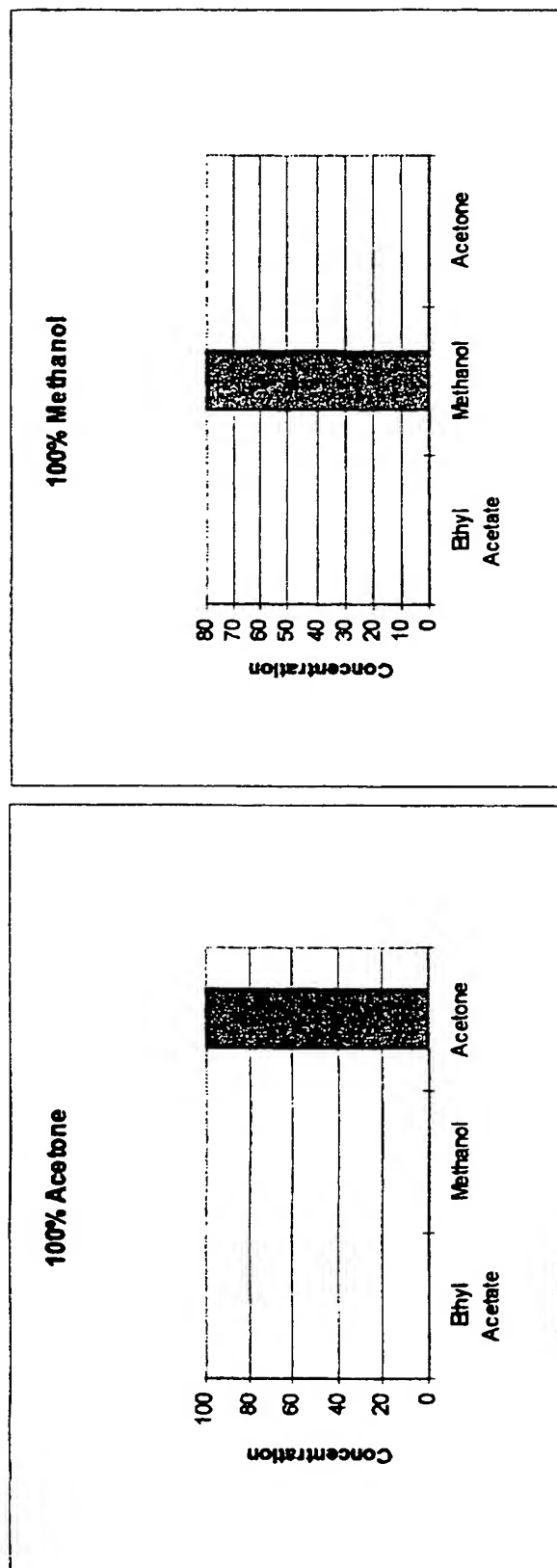


Figure 14
Results of neural network classifications for multi-component vapours

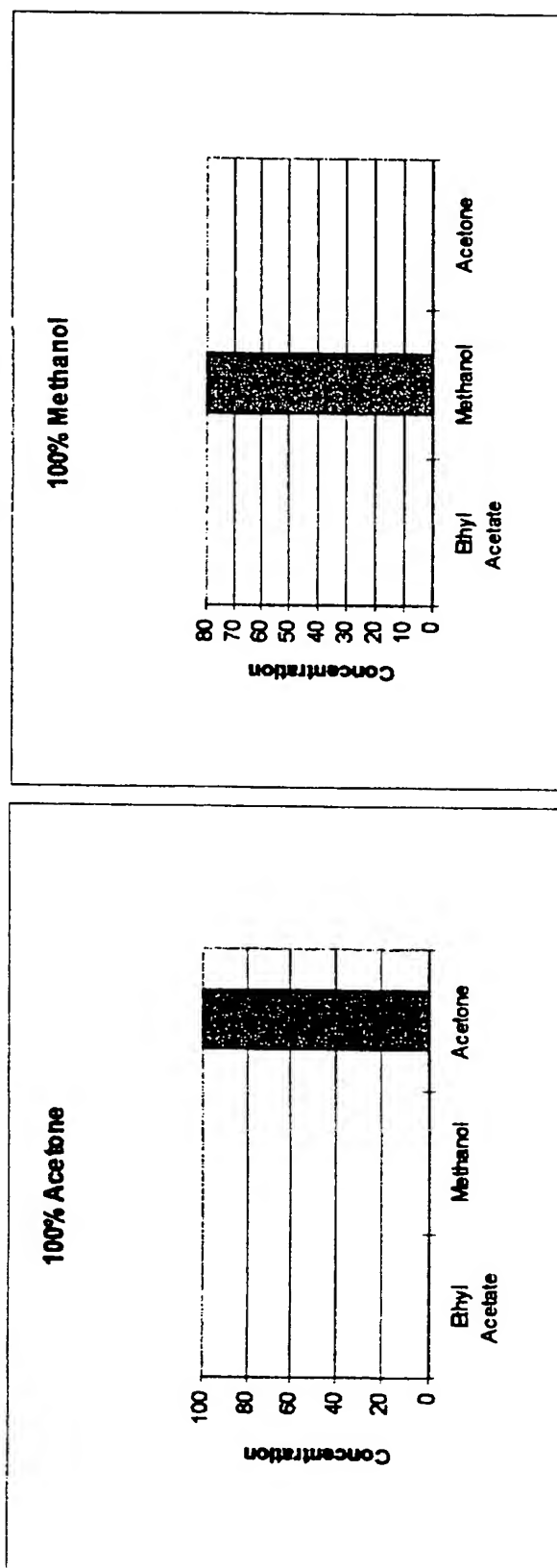


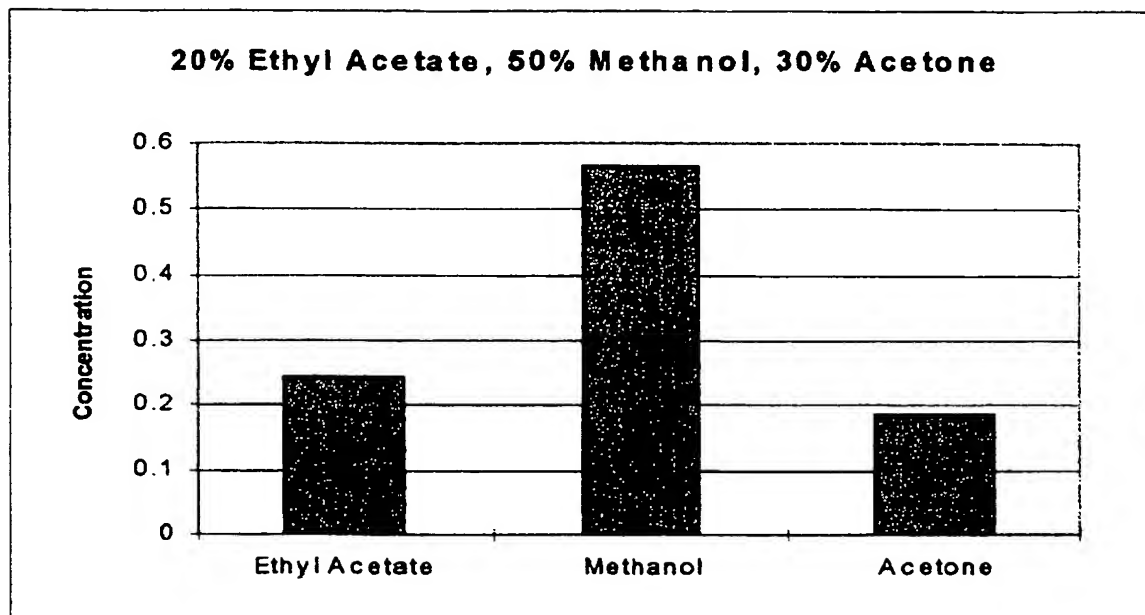
Figure 15**Results of neural network prediction for multi-component vapours**

Figure 16(a)

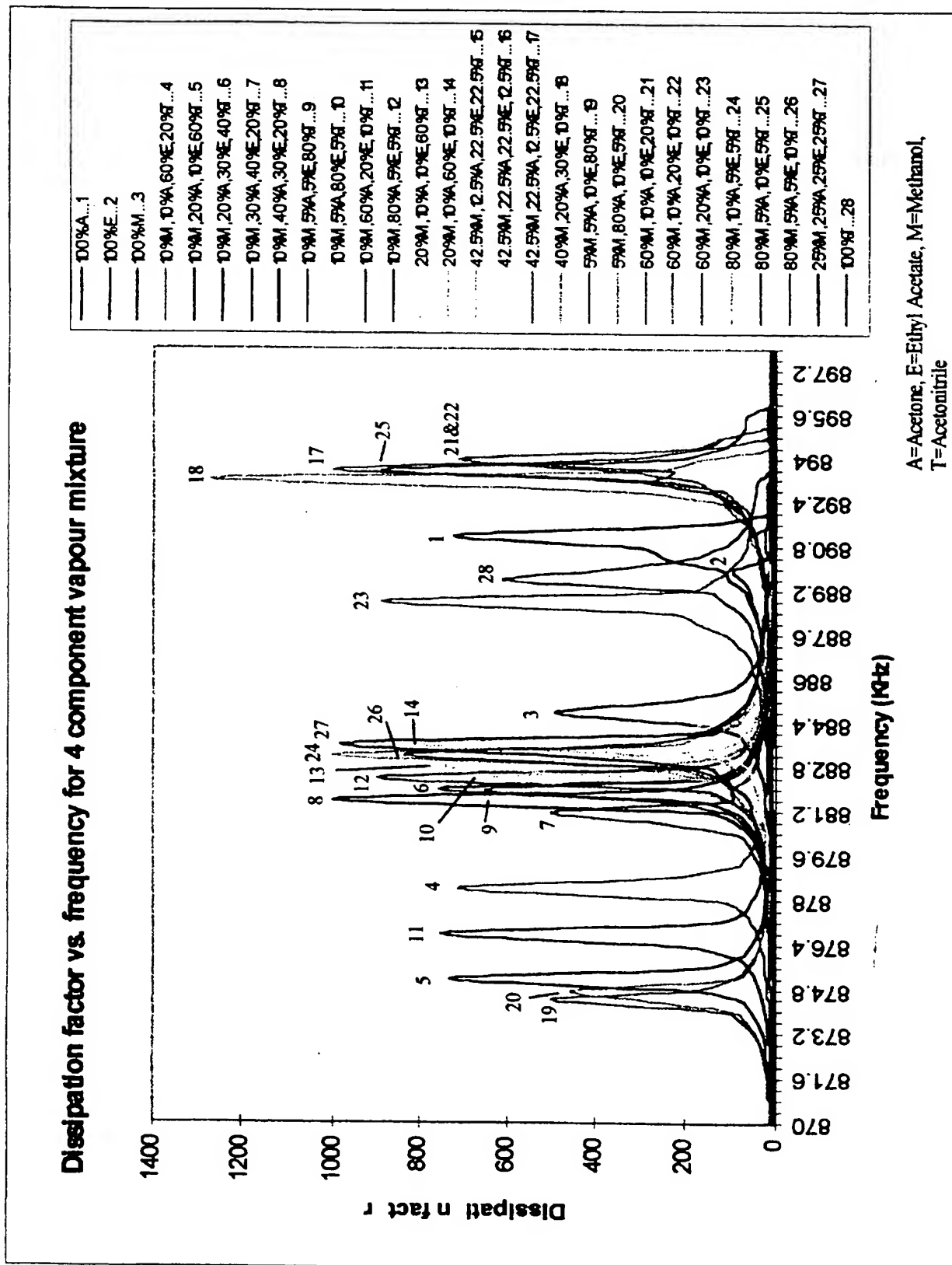
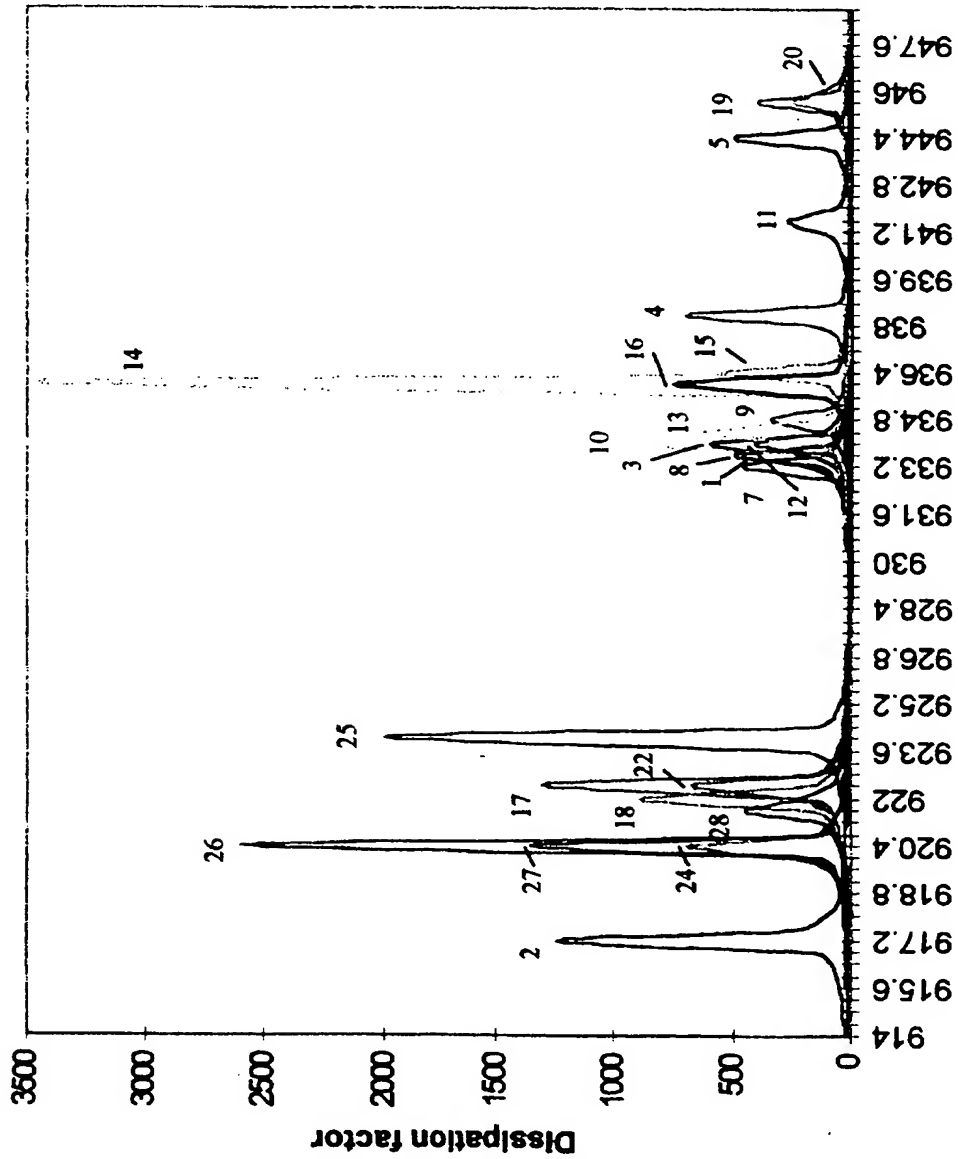


Figure 16(b)

Dispersion factor vs. frequency for 4 component mixture



A=Acetone, E=Ethyl Acetate, M=Methanol,
T=Acetonitrile

Figure 17

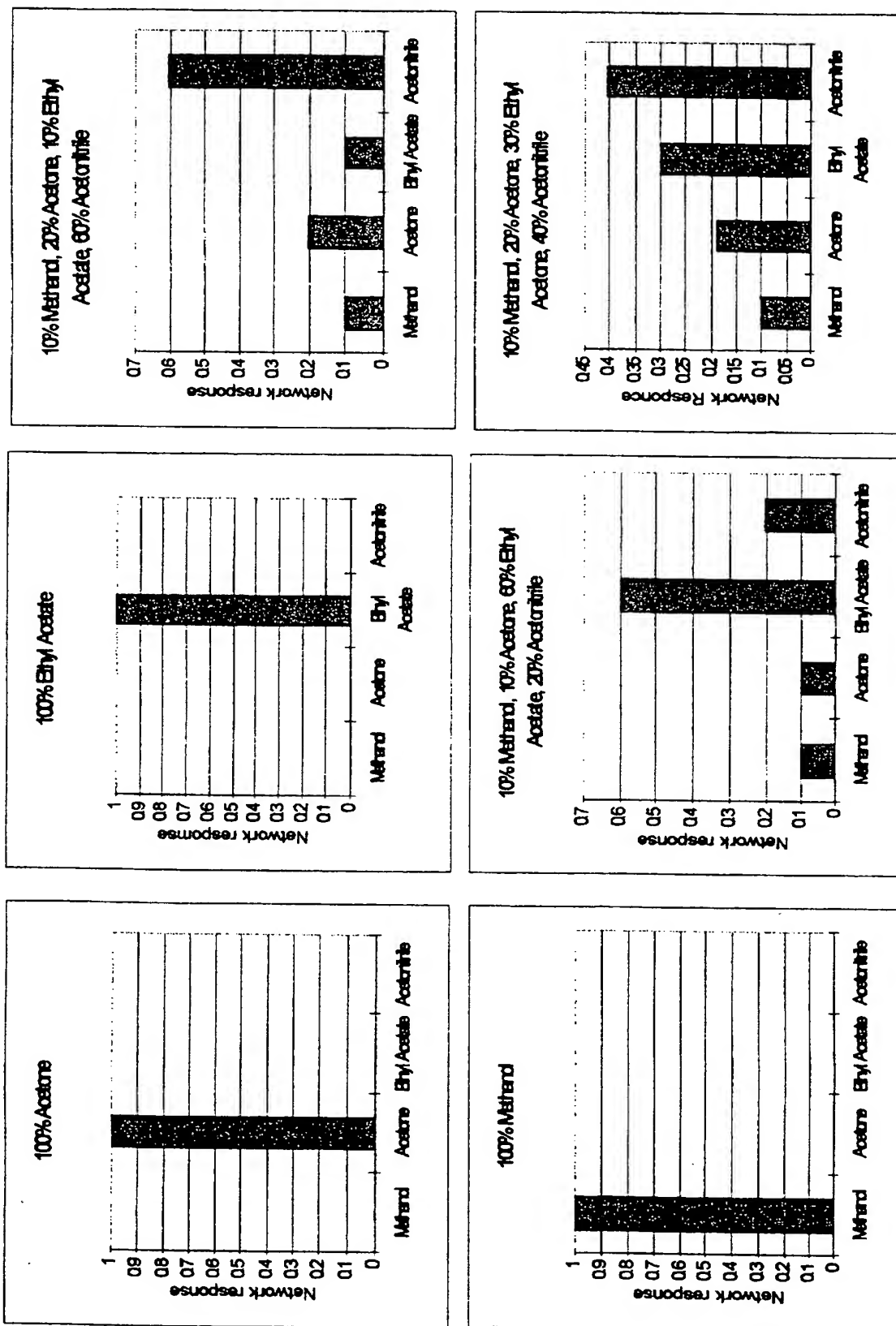


Figure 18

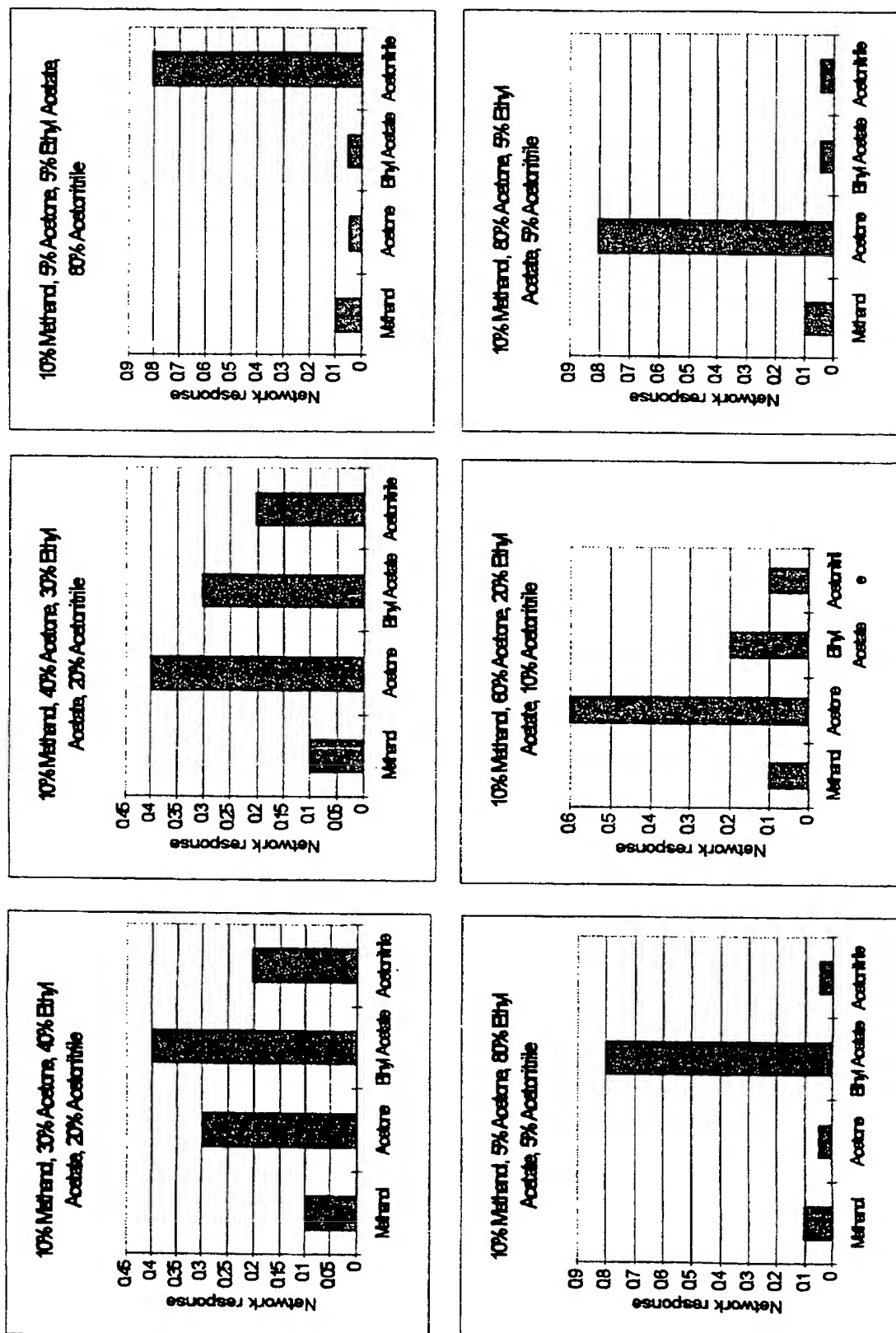


Figure 19

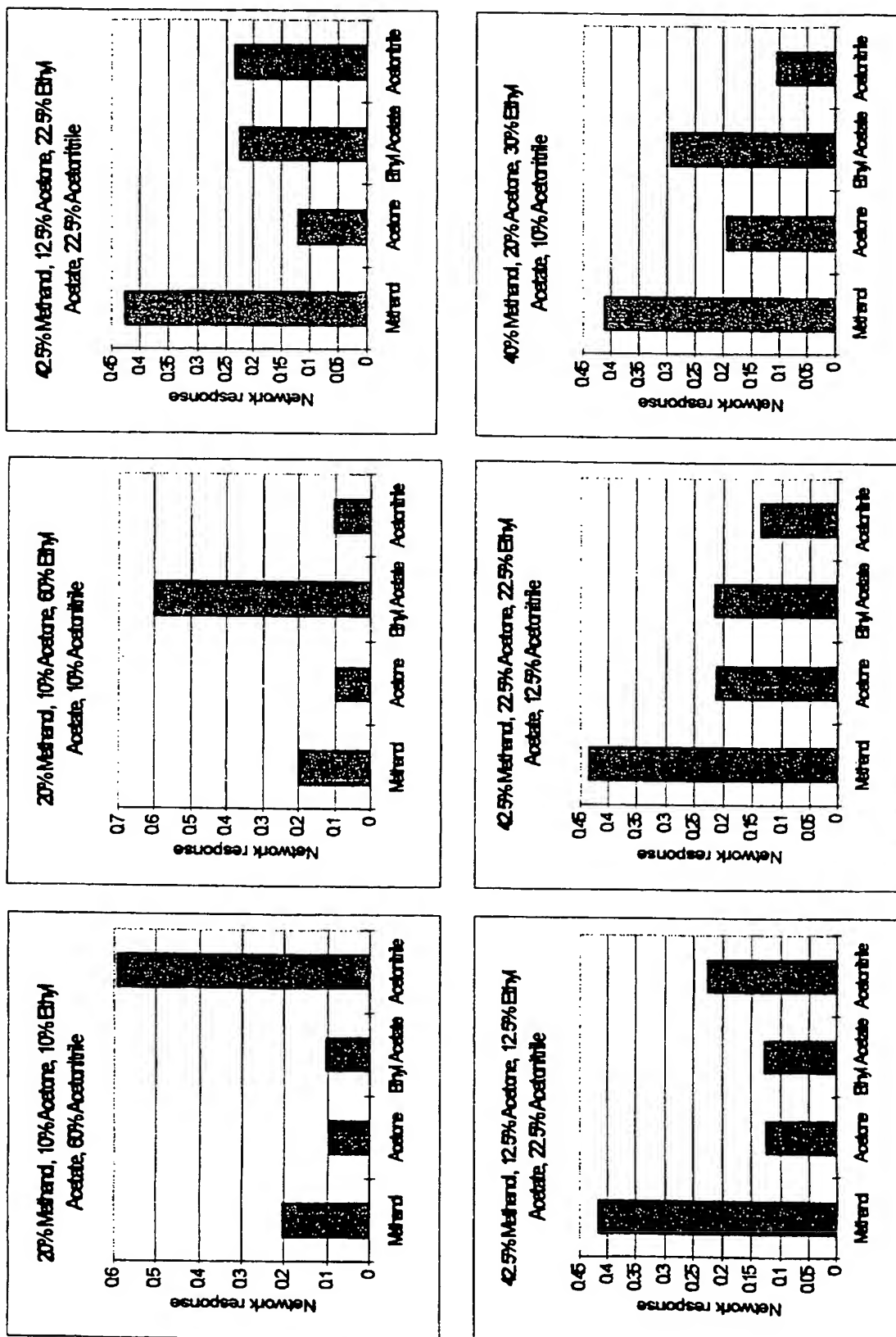


Figure 20

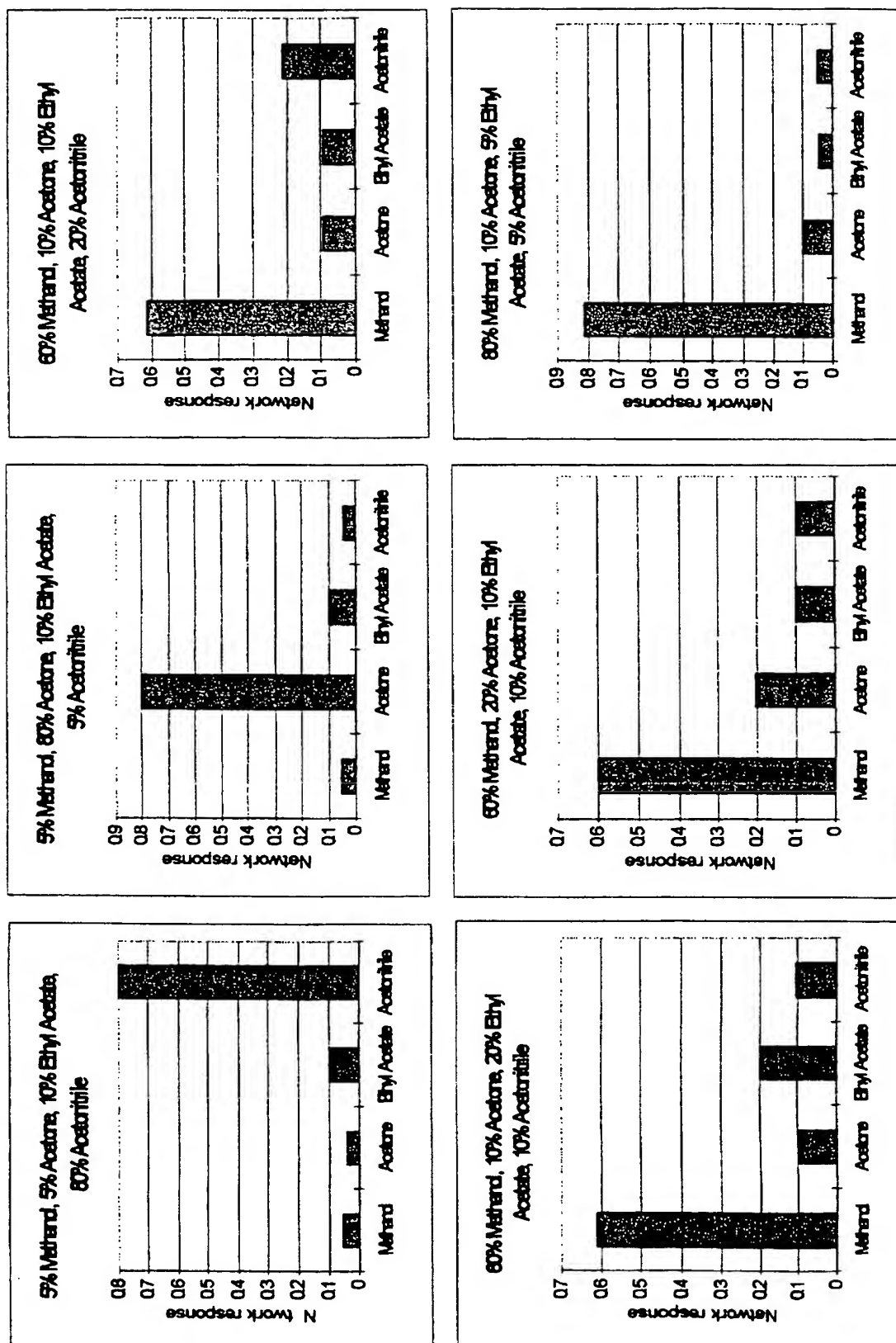
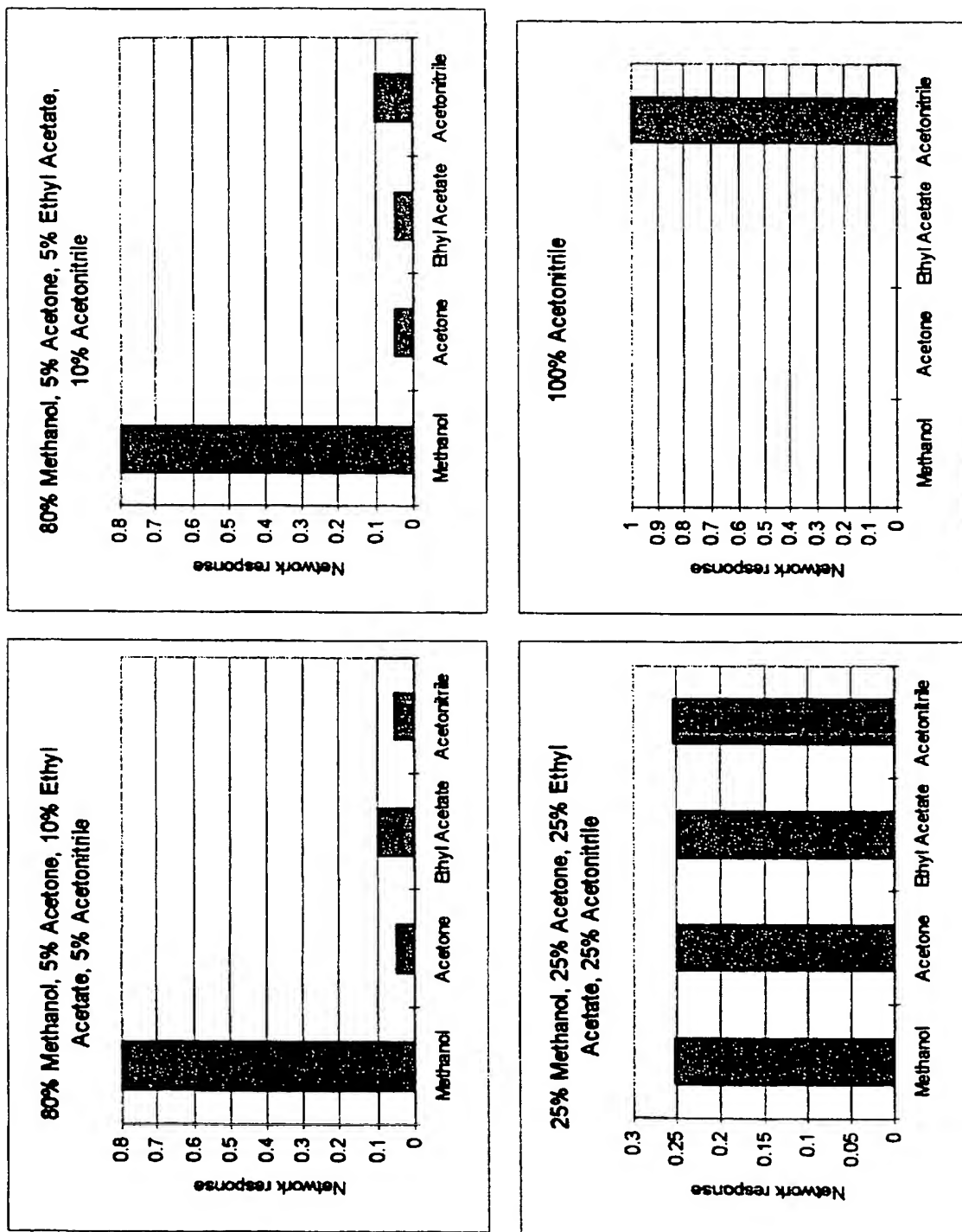


Figure 21



INTERNATIONAL SEARCH REPORT

International Application No
PC 95/03030

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01N33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB,A,2 203 553 (COGENT LTD) 19 October 1988 cited in the application see abstract; figure 3 ---	1
Y	TRENDS IN ANALYTICAL CHEMISTRY, vol. 11, no. 2, February 1992, AMSTERDAM, NL, pages 61-67, XP000247333 K. C. PERSAUD: "ELECTRONIC GAS AND ODOUR DETECTORS THAT MIMIC CHEMORECEPTION IN ANIMALS" see the whole document ---	1
A	EP,A,0 431 910 (THE GENERAL ELECTRIC COMPANY) 12 June 1991 see claims 4,6 --- -/--	1

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

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- *&* document member of the same patent family

Date of the actual completion of the international search

19 June 1996

Date of mailing of the international search report

26.07.96

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Authorized officer

Duchatellier, M

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 95/03030

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>SENSORS AND ACTUATORS A - PHYSICAL, vol. A45, no. 2, 1994, LAUSANNE, CH, pages 159-165, XP000482622 BYEONGDEOK YEA: "THE DISCRIMINATION OF MANY KINDS OF ODOR SPECIES USING FUZZY REASONING AND NEURAL NETWORKS" see the whole document</p>	1
A	<p>EP,A,0 293 255 (AMERICAN INTELL-SENSORS CORP.) 30 November 1988 see abstract</p>	1

INTERNATIONAL SEARCH REPORT

inform on patent family members

Inter. Appl. Application No

PC 95/03030

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		DE-T- 3885784	19-05-94
		EP-A- 0286307	12-10-88
		ES-T- 2048759	01-04-94
		JP-A- 1026138	27-01-89
		US-A- 4887455	19-12-89
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		DE-D- 69010315	04-08-94
		DE-T- 69010315	27-10-94
		GB-A,B 2239094	19-06-91
		JP-A- 6265499	22-09-94
		US-A- 5239483	24-08-93
EP-A-293255	30-11-88	US-A- 4847783	11-07-89

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